

Sequestration R&D

Program Mission

The mission of the Sequestration R&D program is to create public benefits by discovering and developing ways to economically separate and permanently store (sequester), or to offset, greenhouse gas emissions from the combustion of fossil fuels. A successful research and development effort will allow the continued use of economical fossil fuels during the transition to a hydrogen economy.

About 90% of coal produced in the United States is used for electricity generation and over half of all electricity is produced by coal-fired power plants. Including electricity generated by oil and natural gas-fired power plants, approximately 70% of all electricity produced in the United States is generated from fossil fuels. The continued use of fossil fuels to generate affordable electricity is critically important to the United States economy and the power generation industry needs to maintain a diversified fuel mix to ensure adequate energy supplies at a reasonable price. The continued use of fossil fuels has many environmental challenges, and sustained use could be severely limited unless satisfactory solutions can be found to overcome these environmental challenges, especially with regard to global climate change. For example, the ability to cut the carbon dioxide (CO₂) emissions in the United States by over 16 percent.

Since electric generation is expected to grow and fossil fuels will continue to be the dominant fuel source, there is growing recognition that the public/private collaboration must be part of the solution to curbing greenhouse gas emissions by capturing and permanently sequestering carbon dioxide. The President's recently announced climate change goal is to significantly reduce the greenhouse gas intensity of the United States economy over the next 10 years, while sustaining the economic growth needed to finance investment in new, clean energy technologies. The Carbon Sequestration Program directly supports these and several National Energy Policy (NEP) goals targeting the development of new technologies, market mechanisms, and international collaboration to reduce greenhouse gas intensity and greenhouse gas emissions. The development of carbon capture and sequestration technologies must play a key role if the United States is to set a path to slow the growth of greenhouse gas emissions, and -- if the emerging science justifies -- to stop and then reverse that growth.

The DOE is developing a portfolio of technologies and mitigation strategies designed to reduce the emissions of greenhouse gases using a two-prong approach: (1) Making energy systems more efficient; and; (2) Capture and sequestration of greenhouse gases. The first approach is being addressed by the core fossil energy coal, oil and gas programs and "Vision 21" that is seeking to almost double the current average efficiency of existing coal power plants by 2015. The second approach is being addressed by the Carbon Sequestration R&D Program. The Carbon Sequestration Program is developing a portfolio of technologies that hold great potential to reduce greenhouse gas emissions. The Program will focus primarily on the following areas:

- Developing capture and separation technologies that dramatically lower the costs of reducing carbon dioxide emissions from fossil fuel process treatment.

- Promoting development of the infrastructure required for wide-scale deployment of greenhouse gas mitigation technologies.

The programmatic time line is to develop to a state of commercial readiness a portfolio of safe and cost effective greenhouse gas capture, storage and mitigation technologies by 2012, leading to substantial market penetration beyond 2012. Technology developments within the Sequestration Program are expected to significantly contribute to the President's goal of reducing greenhouse gas intensity by 18% by 2012 and would play a critical role should it be necessary to stabilize greenhouse gas emissions in the United States.

In addition to maintaining core R&D, the Sequestration Program will focus on the follows programmatic thrusts:

- Provide funding support and management assistance for the President's National Climate Change Technology Initiative (NCCTI) competitive solicitation. The NCCTI competitive solicitation is intended to promote applied research, via a series of open competitive solicitations, aimed at exploring concepts, technologies and advanced technical approaches that could, if successful, contribute in significant ways to (a) further reductions in, or avoidance of, greenhouse gas (GHG) emissions; (b) GHG capture and sequestration; and/or (c) conversion of GHGs to beneficial use. The intent of this solicitation is to have all the various technologies that can potentially contribute to the reduction of greenhouse gas emissions or concentrations compete head-to-head based on GHG mitigation. While other projects and programs can contribute to greenhouse gas solutions, those solicitations have required that projects meet other pre-selected technological criteria (solar, nuclear, fossil, ocean, etc.) for consideration. This solicitation will be operated and funded jointly with the Office of Nuclear Energy and the Office of Energy Efficiency and Renewable Energy.
- Pursue sequestration strategies that support zero emissions and waste from energy conversion facilities. These strategies would include the sequestration of greenhouse gases and conventional pollutants and effluents" or waste products, and combine low-cost CO₂ capture with efficiency benefits from new generation technology to achieve low-cost net greenhouse gas emissions reduction. Technology options will be pursued that offer optional pathways to zero emissions energy plants by enabling total sequestration of effluent streams. This activity enables sequestration opportunities that support both the Clear Skies and climate change initiative.
- Strengthen U.S. and DOE leadership in carbon sequestration by pursuing global public/private R&D partnerships. In addition to seeking new opportunities, emphasis will be places on strengthening and expanding existing cooperative efforts with Canada, Japan, Australia, Italy, Norway, and the European Union.
- Accelerate planning of regional carbon sequestration partnerships. This activity focuses on promoting development of the infrastructure for wide-scale deployment of mitigation technologies and place more emphasis on bringing low-cost, value-added CO₂ capture and storage to the commercial implementation stage before 2012, while establishing the longer-term capability for addressing capture and sequestration from power generation, through early

demonstration activities. These partnerships will (1) identify regional opportunities and benefits; (2) create a baseline and characterize a region by match source and sink opportunities; (3) address safety, permitting, public acceptance; and (4) provide technology validation for regional capture and storage opportunities.

- Increase R&D focus on restoration of disturbed lands. Strengthen and expand R&D, including collaboration with the Department of Agriculture, Department of Interior and the Environmental Protection Agency to produce near-term benefits that directly contribute to the 2012 greenhouse gas intensity goal of the Global Climate Change Initiative.
- Accelerate Novel Sequestration Systems R&D to create expanded and new means of storing or reusing carbon and other greenhouse gas residuals that provide additional pathways to near zero emissions energy facilities of the future. Strong emphasis will be placed on technologies that offer permanent “solid” storage using chemical/biological pathways to inert, benign solids and useful products. These efforts will be coordinated with the DOE Office of Science, National Academy of Sciences, the IEA/GHG and other science organizations involved in this area.
- Aggressively pursue a new R&D thrust on non-CO₂ greenhouse gases, with emphasis on mitigating methane emissions. Cooperative efforts with Department of Agriculture and the Environmental Protection Agency R&D on mitigation strategies related to landfills, coalbeds and fugitive emissions will enable leveraging of R&D funds and could produce near-term benefits that directly contribute to the 2012 greenhouse gas intensity goal of the Global Climate Change Initiative.

Program Specific Performance Goal

ER 4-3: By 2007 demonstrate at a pilot plant scale, technologies to reduce the cost of carbon separation and capture from new coal-based power systems by 75 percent compared to current systems (\$200/tonne carbon in year 2000). By 2012, develop technologies that result in less than 10 percent increase in the cost of new energy services to separate, capture, transport, and sequester carbon using either direct or indirect systems.

Performance Indicator: Number of tests of strategies, concepts and technologies required to reduce the cost of carbon capture by 70 percent.

Annual Performance Targets and Results

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
Complete the injection of 2,500 tons of CO ₂ into a depleting oil reservoir to monitor the transport of CO ₂ and verify predictive geologic models on reservoir integrity.	Establish modular carbon dioxide capture test facility. This facility will accelerate development and testing of emerging low-cost separation and capture technologies while	Provide funding support and management assistance to the President’s National Climate Change Technology Initiative (NCCTI) competitive solicitation. Ensure

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
	<p>facilitating partnerships with leading technology developers and academic institutions.</p> <p>Complete initial set of field tests of advanced monitoring and verification methods for carbon inventories on natural and engineered terrestrial systems and establish a database for mid-continent planning of geological storage projects.</p> <p>Initiate evaluations of three novel concepts, comprising integrated sequestration with enhanced coal bed methane recovery, mineral carbonation, and CO₂ flooding during enhanced oil recovery and establish initial recommendations for long-term monitoring of CO₂ geological storage to assure acceptability as a safe, long-term storage option.</p> <p>Complete initial planning, field testing, or analyses of sequestration concepts involving saline aquifer storage, ocean storage, and scientific feasibility of CO₂ storage as hydrate on the ocean floor, and complete initial comparative evaluation of energy technology scenarios to identify promising concepts for CO₂ sequestration.</p>	<p>complementary linkages between NCCTI and carbon sequestration program.</p> <p>Initiate start-up of at least five regional carbon sequestration partnerships. Partnerships to identify best regional technology options and source/sink locations for capture and sequestration.</p> <p>Complete initial field tests and development of preliminary standard procedures for advanced monitoring and verification of carbon inventories that will achieve cost reductions and improved measurement speeds in conducting soil and forest carbon measurements on disturbed, unproductive, and productive lands. Success will be measured by reducing the cost from more than \$10/sample to less than \$2/sample.</p> <p>Develop a catalytic reduction technology to mitigate methane emissions from coal mine ventilation air. By converting methane to carbon dioxide and capturing the thermal energy, greenhouse gas potential is reduced by 87% compared to fugitive methane emission.</p> <p>Complete endurance testing of polymeric membranes. Validate performance of oxygen transport membrane. Complete pilot verification of dry regenerable</p>

FY 2002 Results	FY 2003 Updated Targets	FY 2004 Targets
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sorbents. These activities are expected to lead to 10-30% reduction in the cost of capture.

Complete site design and development for the slant hole application for coal seam sequestration. Complete deep well and geologic characterization in saline aquifer in West Virginia. These activities will quantify storage potential and validate these sequestration options.

Funding Profile

(dollars in thousands)

	FY 2002 Comp. Approp.	FY 2003 Request	FY 2004 Base	FY 2004 Request	FY 2004 Request vs. Base	
					\$ Change	% Change
Sequestration R&D	\$31,486	\$44,000	\$44,000	\$62,000	\$18,000	40.9%
Total, Sequestration R&D	\$31,486	\$44,000	\$44,000	\$62,000	\$18,000	40.9%

Funding by Site

(dollars in thousands)

	FY 2002	FY 2003	FY 2004	\$Change	%Change
Argonne National Lab	\$120	\$120	\$0	\$-120	-100.0%
Idaho Nat'l Engineering and Environmental Lab	862	862	0	-862	-100.0%
Lawrence Berkeley National Lab	450	1,050	150	-900	-85.7%
Lawrence Livermore National Lab	355	350	250	-100	-28.6%
Los Alamos National Lab	1,545	1,705	250	-1,455	-85.3%
National Energy Technology Lab	5,597	7,425	6,930	-495	-6.7%
Oak Ridge National Lab	633	682	550	-132	-19.4%
Pacific Northwest National Lab	170	0	0	0	??
Sandia National Lab	450	900	0	-900	-100.0%
All Other	21,304	30,906	53,870	22,964	74.3%
Total, Sequestration R&D	\$31,486	\$44,000	\$62,000	\$18,000	40.9%

Site Description

Argonne National Laboratory

The Argonne National Laboratory (ANL), located in Argonne, Illinois, is a major multi-program laboratory managed and operated for the U.S. Department of Energy (DOE) by the University of Chicago under a performance-based contract. Argonne research for the Fossil Energy Sequestration R&D program supports DOE strategies to capture CO₂ from existing and advanced fossil fuel conversion systems.

Idaho National Engineering and Environmental Laboratory

The Idaho National Engineering and Environmental Laboratory (INEEL), located outside of Idaho Falls, Idaho, conducts research on breakthrough concepts to separate and capture CO₂.

Lawrence Berkeley National Laboratory

The Lawrence Berkeley National Lab (LBNL), located in Berkeley, California, conducts research and development on geologic sequestration approaches and measurement, monitoring, and verification protocols.

Lawrence Livermore National Laboratory

The Lawrence Livermore National Lab (LLNL), located in Livermore, California, conducts research and development in the area of Sequestration R&D to increase the knowledge base in geologic and oceanic sequestration.

Los Alamos National Laboratory

The Los Alamos National Laboratory (LANL), located in Los Alamos, New Mexico, conducts research and development in the area of Sequestration R&D to lower the costs of CO₂ capture, provide fundamental scientific information on engineered terrestrial sequestration approaches, and develop advanced instrumentation to measure and validate terrestrially sequestered carbon.

National Energy Technology Laboratory

The National Energy Technology Laboratory (NETL), located in Morgantown, West Virginia, Pittsburgh, Pennsylvania, and Tulsa, Oklahoma, is a multi-purpose laboratory, owned and operated by the U.S. Department of Energy. NETL conducts research and development activities in carbon sequestration technologies, focusing on advanced CO₂ separation and capture concepts for both existing and advanced fossil fuel conversion systems, developing and validating modeling methodologies that are transparent and based on laboratory and field data that assess the effectiveness and efficiency of geologic sequestration and provide a sound basis for large-scale demonstration projects, developing and testing measurement, monitoring, and verification protocols, and the role of hydrates in deep ocean sequestration concepts.

Oak Ridge National Laboratory

The Oak Ridge National Laboratory (ORNL), located in Oak Ridge, Tennessee, conducts research and development in the area of Sequestration R&D to further geologic sequestration concepts, including measurement, monitoring and verification, and to understand the important soil parameters that facilitate terrestrial sequestration.

Pacific Northwest National Laboratory

The Pacific Northwest National Laboratory (PNNL), located in Richland, Washington, conducts research and development in the area of Sequestration R&D to accelerate implementation of large-scale engineered terrestrial sequestration approaches, and provides rationale and strategy related to global energy issues related to greenhouse gas mitigation approaches.

Sandia National Laboratory

The Sandia National Laboratory (SNL), located in Albuquerque, New Mexico, conducts research and development in the area of Sequestration R&D on injection of CO₂ into depleted oil and gas formations, and advanced monitoring methodologies based on advances seismic concepts.

All Other

The Department's Sequestration R&D program, within the Fossil Energy and Development program, funds research at major performers at non-DOE locations. Examples of these performers include the CO₂ Capture Project (CCP), a collaborative effort involving nine major international energy companies, that has the goal of developing advanced technologies to significantly (75%) reduce the costs of capturing CO₂ from fossil fuel energy systems, an advanced fossil fuel conversion process with inherent CO₂ capture (Alstom), development of a combined membrane-fossil fuel combustion system that would produce a pure stream of CO₂ for sequestration (Praxair), and testing a regenerable sorbent system capable of capturing CO₂ from advanced coal gasification systems (RTI).

The Sequestration R&D program also funds research at major colleges and universities—developing an accurate cost and performance model for CO₂ capture systems (CMU); using hardwoods to restore mine lands (University of Kentucky); developing a carbon management geographic information system (MIT)—and at non-governmental organizations such as the Nature Conservancy who is developing a carbon accounting system for large forest ecosystems.

Detailed Program Justification

(dollars in thousands)

	FY 2002	FY 2003	FY 2004
Sequestration	31,486	44,000	62,000

The Carbon Sequestration Program is developing a portfolio of technologies that holds great potential to reduce greenhouse gas emissions.

■ Greenhouse Gas Control	26,164	36,135	41,250
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Refocus core R&D program toward meeting the goals of in the following areas: developing efficient, low-cost, advanced CO₂ separation and capture concepts; identifying issues associated with carbon sequestration in differing geologic formations, and reducing the cost, and environmental uncertainties (including storage stability, permanence, rates and characteristics of migration) of large-scale carbon sequestration through innovative Public-Private R&D partnerships. Close collaboration with the carbon management science programs and activities in the Office of Science will be maintained for the purposes of applying promising basic science principles to novel concepts, thereby providing an integrated approach to advancing the science and technology of carbon sequestration. *Participants include: NETL, LANL, Battelle, Praxair, Dakota Gasification, ARI, Nature Conservancy, Univ. Of KY, Univ. of TX, VA Tech, MIT, Princeton University, Consol, IEA, TBD.*

FY 2003 and FY 2002 funding continued development of models and predictive tools that will be required to assess the effectiveness of sequestration, advanced CO₂ capture approaches that are significantly less costly (capital and energy penalty costs), practical sequestration technologies specific to the types of geologic reservoirs found in the U.S., advanced fossil fuel conversion systems that produce a concentrated stream of CO₂ ready for sequestration, and measures to capture and control non-CO₂ greenhouse gases, and issue a solicitation for the Integrated Sequestration and Hydrogen Initiative. *Participants included: RTI, Media Processing Technology, LBNL, LLNL, ORNL, Texas Tech University, University of Kansas, TVA, MBARI, Alabama Geological Survey, Ohio University, PSU, University of Utah, OSU.*

■ Focus Area for Carbon Sequestration Science . . .	5,000	7,425	6,930
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Refocus activities toward the areas of capture, geologic and deep ocean CO₂ sequestration, establish the scientific and technical bases needed to cost-effectively capture and permanently sequester CO₂. *Participants include: NETL.*

FY 2003 and FY 2002 funding continued development of wet scrubber systems to concentrate CO₂ from coal-fired power plants, facilities to test and evaluate advanced CO₂ capture systems applicable to both existing and advanced coal conversion processes and determine CO₂ flow characteristics in brine formations and coal seams, a state-of-the-art facility to mimic the formation of CO₂ hydrates in the deep ocean, and models to predict the extent of and verify sequestration of CO₂ in brine formations and in coals seams. *Participants included: NETL*

(dollars in thousands)

	FY 2002	FY 2003	FY 2004
■ National Climate Change Technology Initiative . .	0	0	13,200
Provide funding support and management assistance for the President's National Climate Change Technology Initiative (NCCTI) competitive solicitation. The NCCTI competitive solicitation is intended to promote applied research, via a series of open competitive solicitations, aimed at exploring concepts, technologies and advanced technical approaches that could, if successful, contribute in significant ways to (a) further reductions in, or avoidance of, greenhouse gas (GHG) emissions; (b) GHG capture and sequestration; and/or (c) conversion of GHGs to beneficial use. This solicitation will be operated and funded jointly with the Office of Nuclear Energy and the Office of Energy Efficiency and Renewable Energy. <i>Participants to be determined.</i>			
No FY 2003 and FY 2002 funding was requested for this activity in this account.			
■ Program Support	322	440	620
Fund technical and program management support.			
Total, Sequestration R&D	31,486	44,000	62,000

Explanation of Funding Changes

	FY 2004 vs. FY 2003 (\$000)
■ Increase in Greenhouse Gas Control due to expansion of base programs	5,115
■ Decrease in Focus Area for Carbon Sequestration Science due to decreased level of in-house effort	-495
■ Increase in National Climate Change Technology Initiative due to start of new initiative	13,200
■ Increase in Program Support due to additional feasibility studies	180
Total Funding Change	18,000